

# **Geologic Control of Soil Carbon Sequestration – *Examples from Western Conifer Forests***

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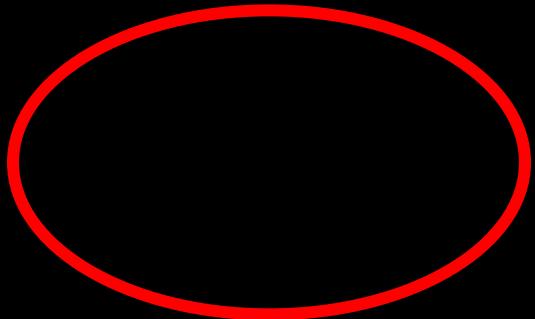
# Global Carbon Cycle – why do we care?



# Global Carbon Cycle

## Pool size and flux

Atmospheric CO<sub>2</sub> sinks:  
land-atmosphere;  
ocean-atmosphere



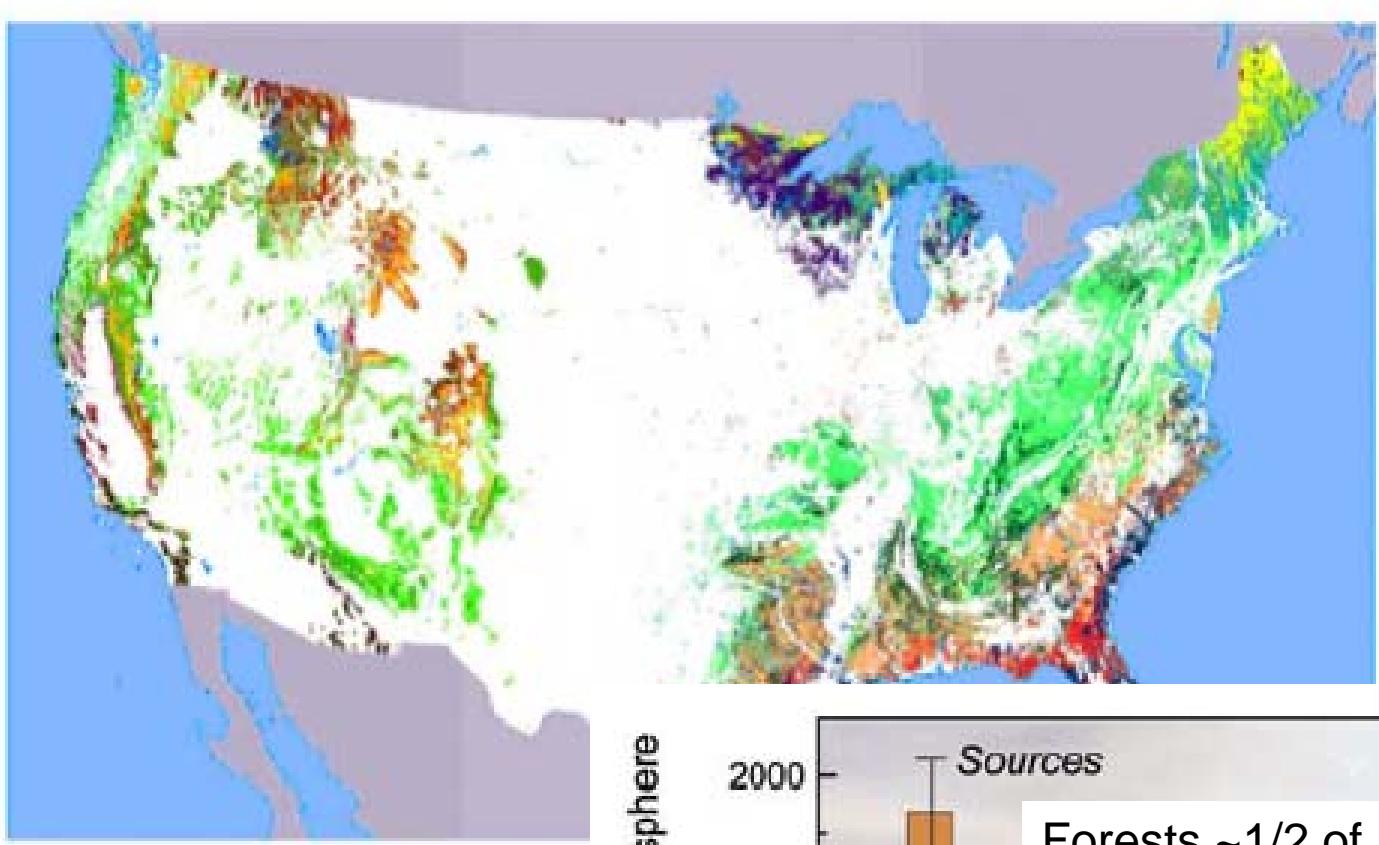
Soil carbon – largest  
terrestrial pool

Source/sink dynamic

# Terrestrial Carbon Stocks

Ecosystem Type	Soil Carbon mt C x 10 <sup>9</sup>	Litter Carbon	Total Carbon	% of Total
Tropical Forest	255	3.6	259	17
Temperate Forest	142			10
Boreal Forest	179	24.0	203	13
Woodland and Shrubland	59	2.4	61	4
Tropical Savanna	56	1.5	58	4
Temperate Grassland	173	1.8	175	12
Tundra and Alpine	173	4.0	177	12
Desert Scrub	101	0.2	101	7
Extreme	3	0.0	3	0
Cultivated	178	0.7	179	12
Swamp and Marsh	137	2.5	140	9
<b>Total</b>	<b>1456</b>	<b>55</b>	<b>1511</b>	

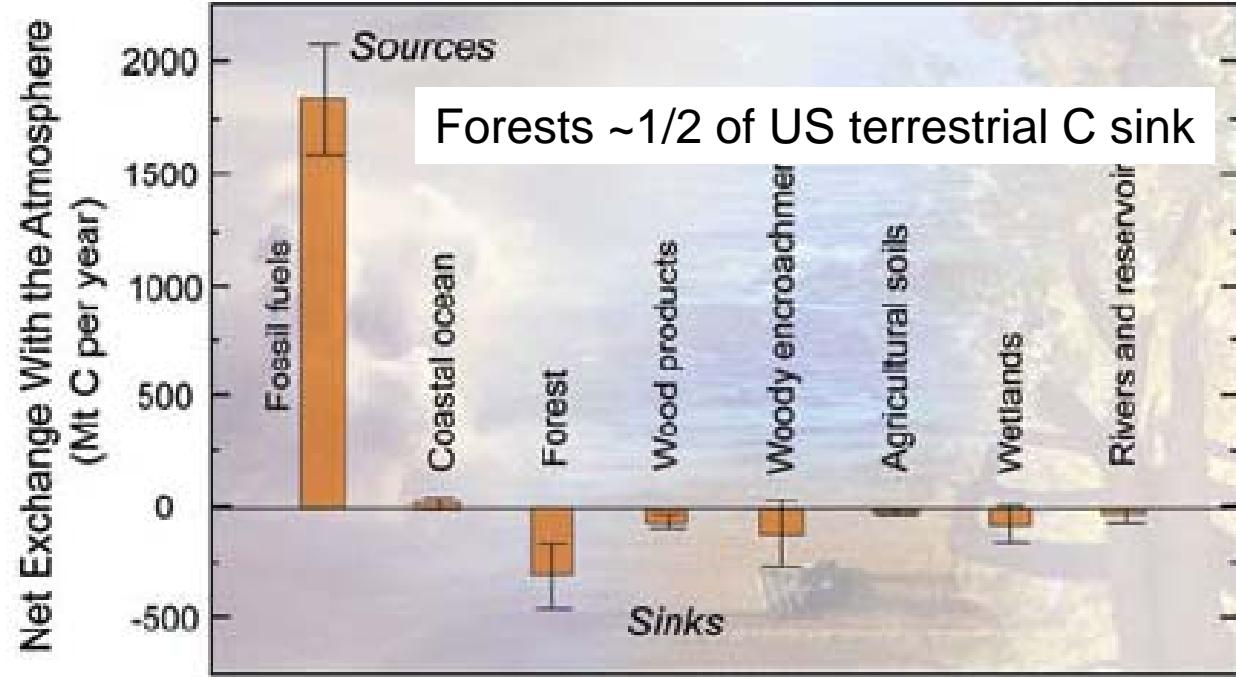
From Schlesinger (1992)



North America Carbon Stocks

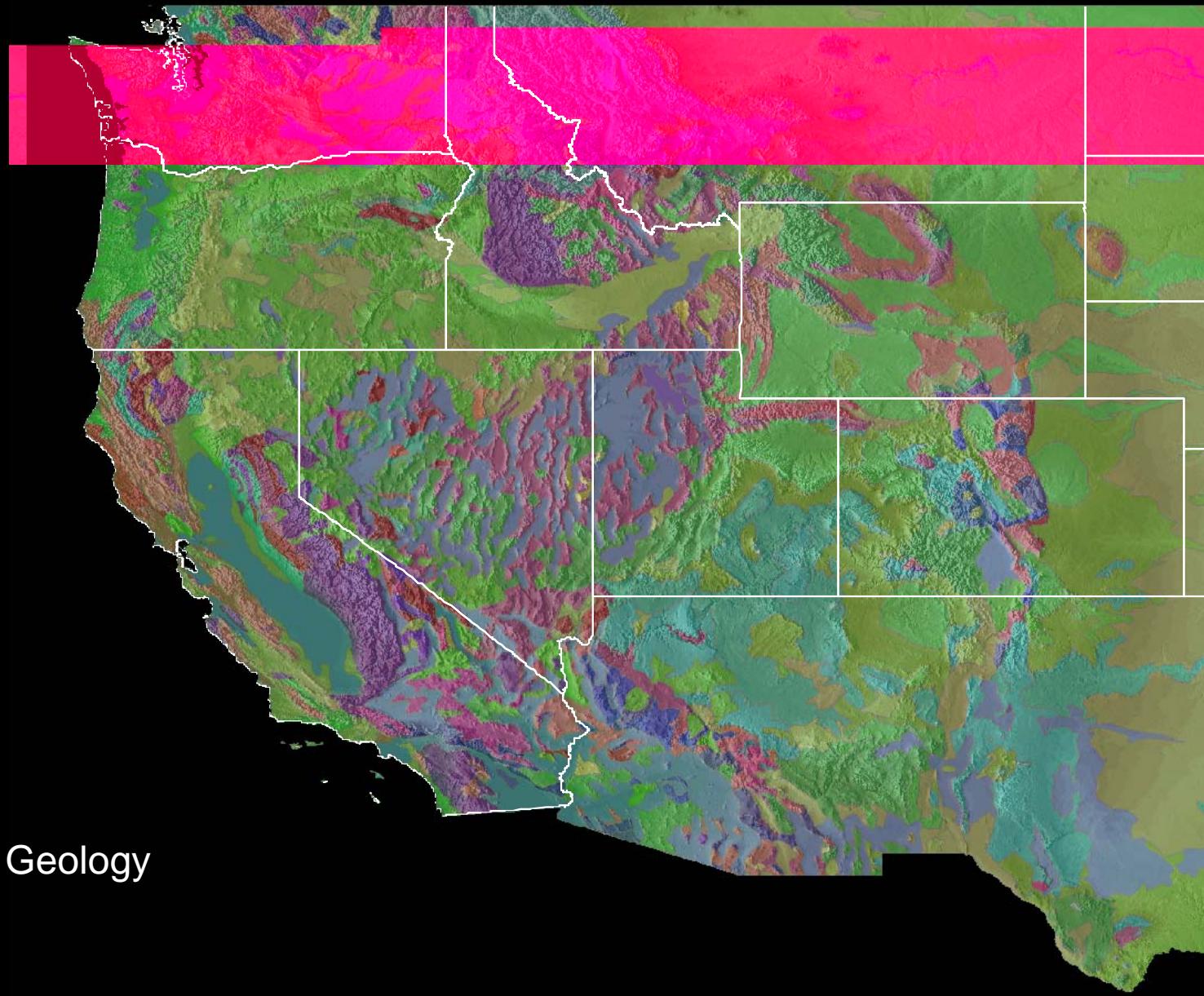
Forests – east and west

West predominantly conifer forests



# Western Conifer Forests

- Complex physiography
  - Geology
  - Climate
  - Ecosystems
- California and Arizona



Bedrock Geology



**Winter**

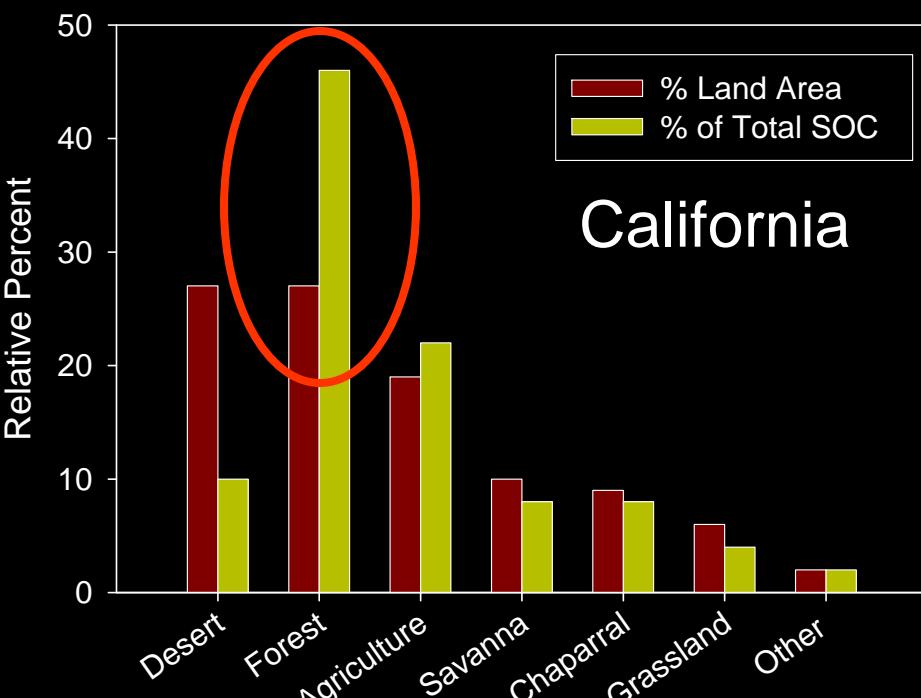
**Xeric**



**Summer**

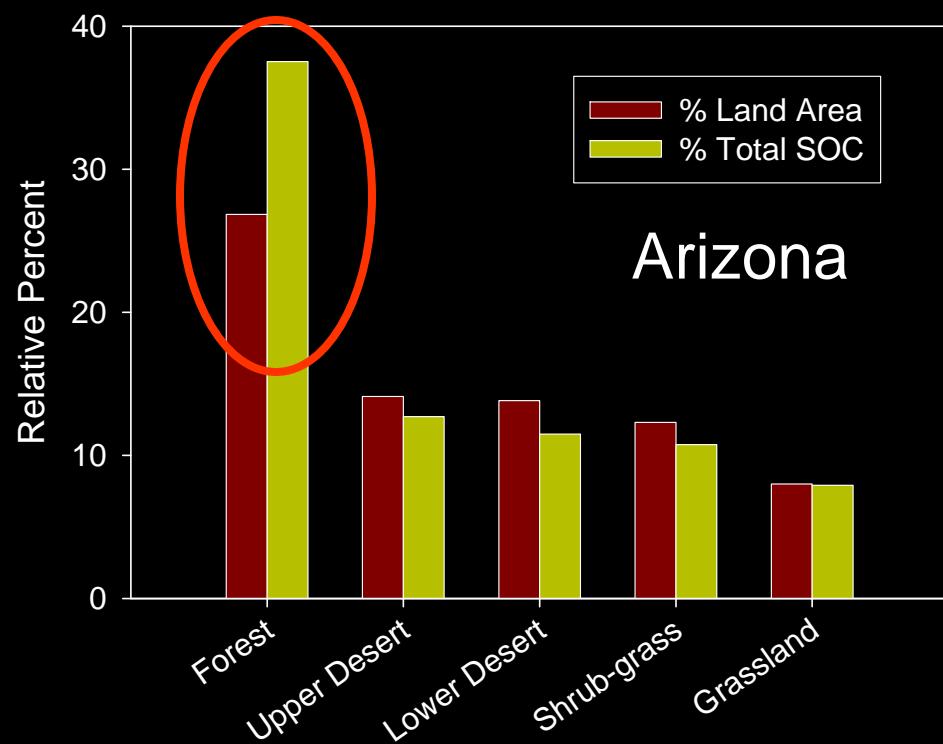
**Ustic**





Forests – disproportionate SOC relative to land area

Clay content not a good predictor of SOC in these systems



# California Conifer Ecosystems

Significant difference in  
SOC content among  
geologic parent materials

Parent Material	SOC ( $\text{kg m}^{-2}$ )
Andesite	8.7 A
Basalt	8.1 B
Granite	5.9 C

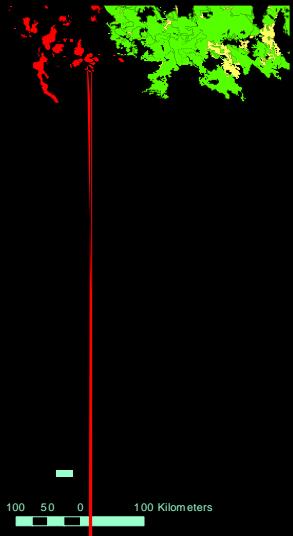
# How does geology control SOC sequestration?

- Metal and mineral interactions
  - Organo-metal complexation
  - Mineral adsorption
- Microbial community composition
  - Diversity and function
- Aggregation
  - Mineral-mineral and organo-mineral
  - Occlusion and physical protection
- *All are highly dependent on soil mineral assemblage and should vary predictably with geologic parent material*

# Geology and Soil Carbon Studies

- Case studies
  - Sierra Nevada Conifer Forests
    - Parent material and elevation gradients
  - Arizona Ponderosa Pine Forests
    - Soil pH and Al gradient
- Empirical and Mechanistic data
  - Soil C mineralization
  - Microbial community composition
  - Aggregate stability and occlusion

# Study 1: Sierra Nevada Forests

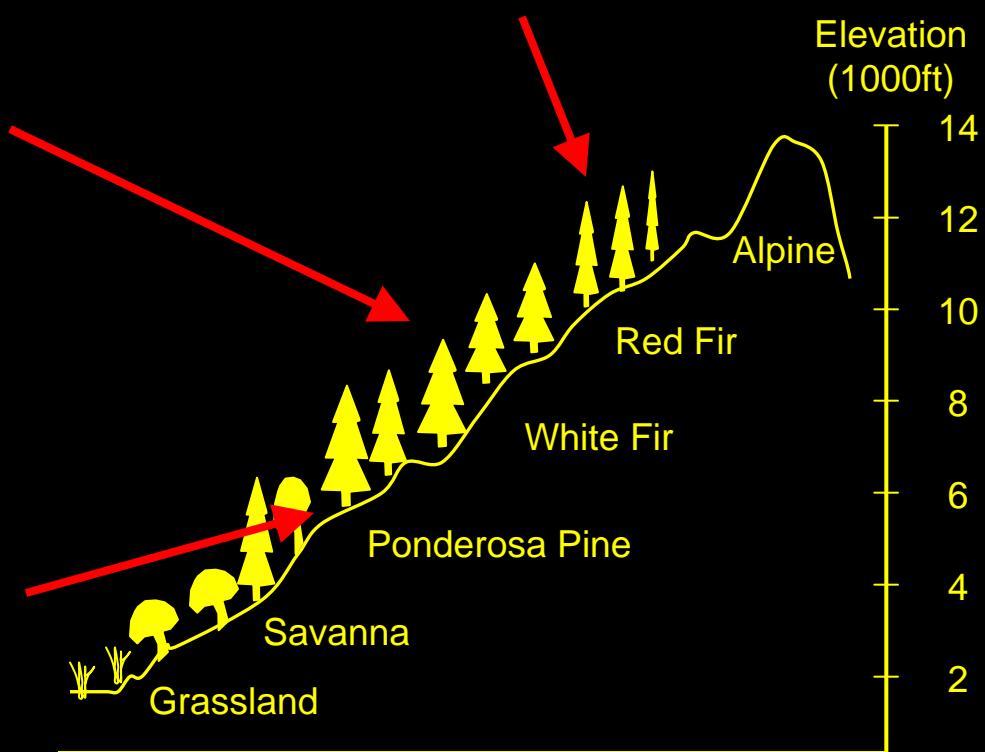


- Three elevation gradients on three igneous parent materials:
  - Granite (GR), Andesite (AN), Basalt (BS)
- Three conifer ecosystems:
  - *Pinus ponderosa* (pp), *Abies concolor* (wf), *A. magnifica* (rf)
- Very different mineral assemblages

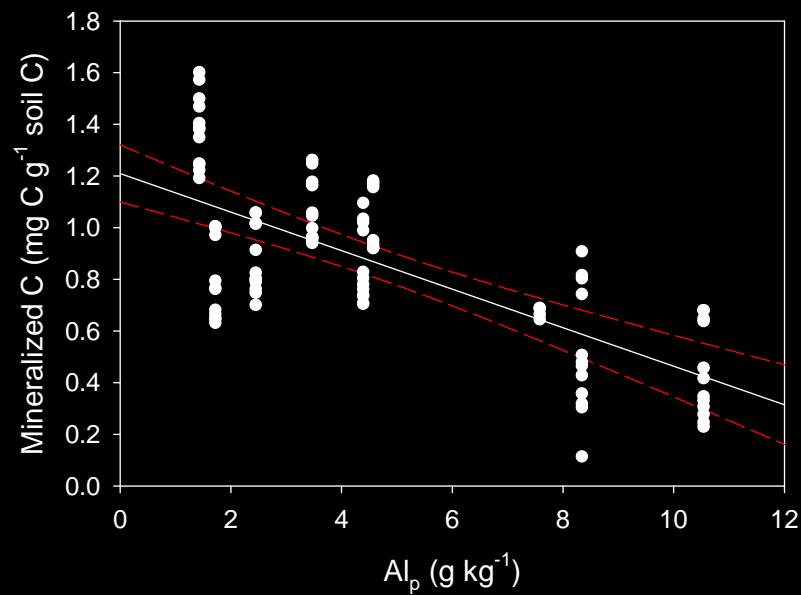
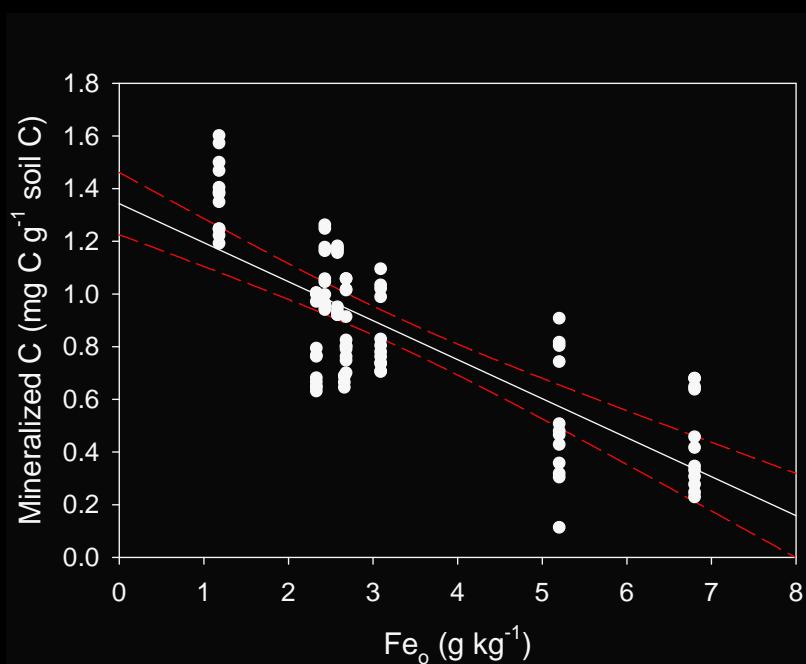
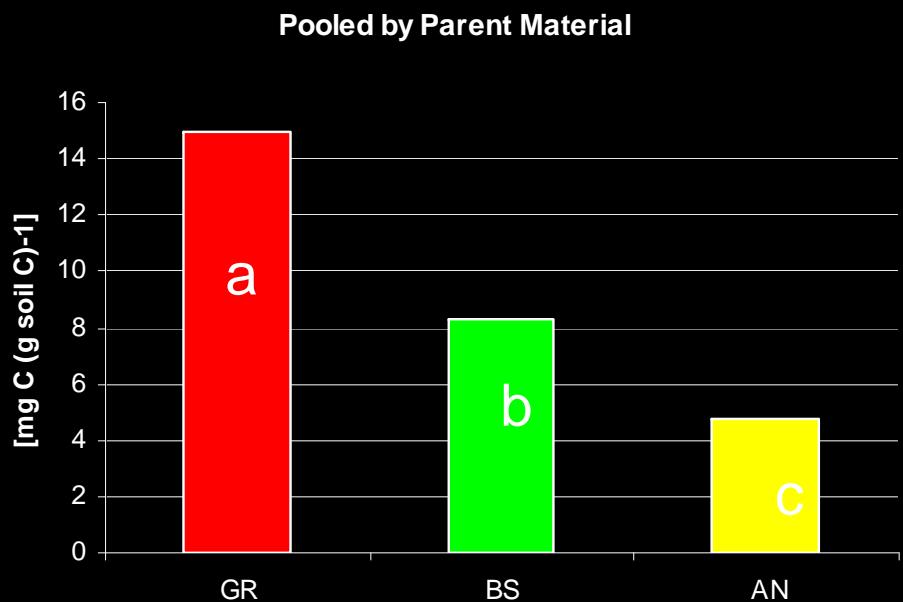
Red Fir, MAST 0-8°C, Entisols

White Fir, MAST 8-10°C,  
Inceptisols/Andisols

Ponderosa Pine, MAST 10-15°C,  
Alfisols/Ultisols

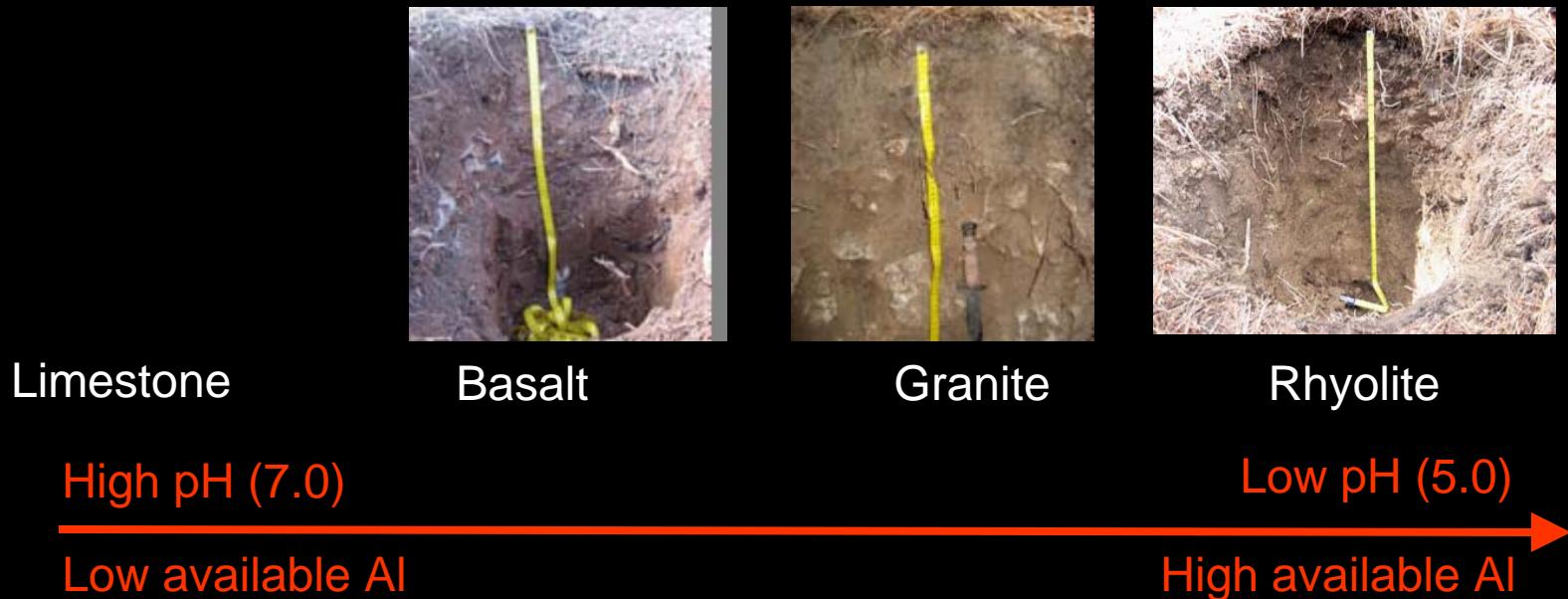


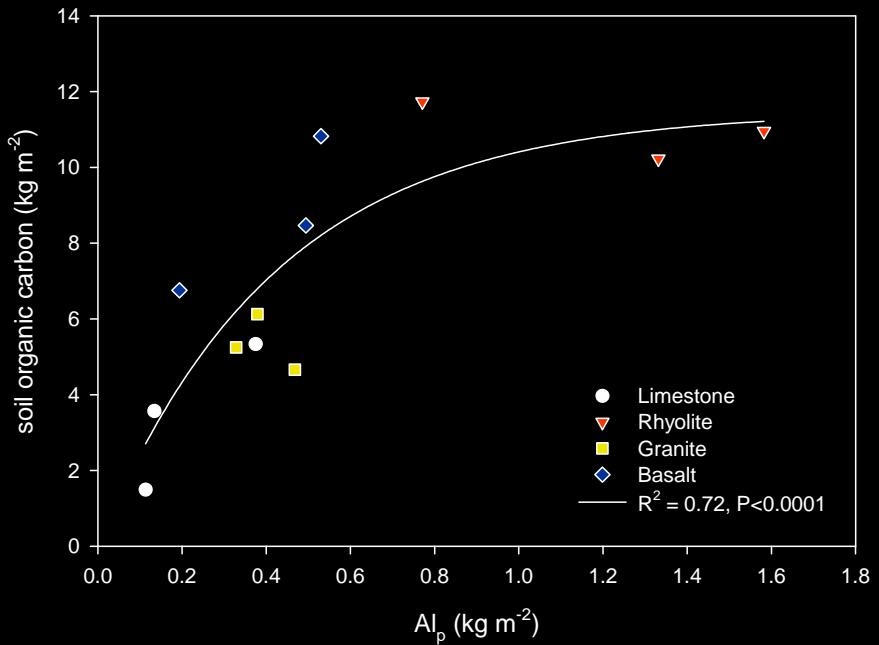
# Soil C Mineralization



# Study 2: Arizona Forests

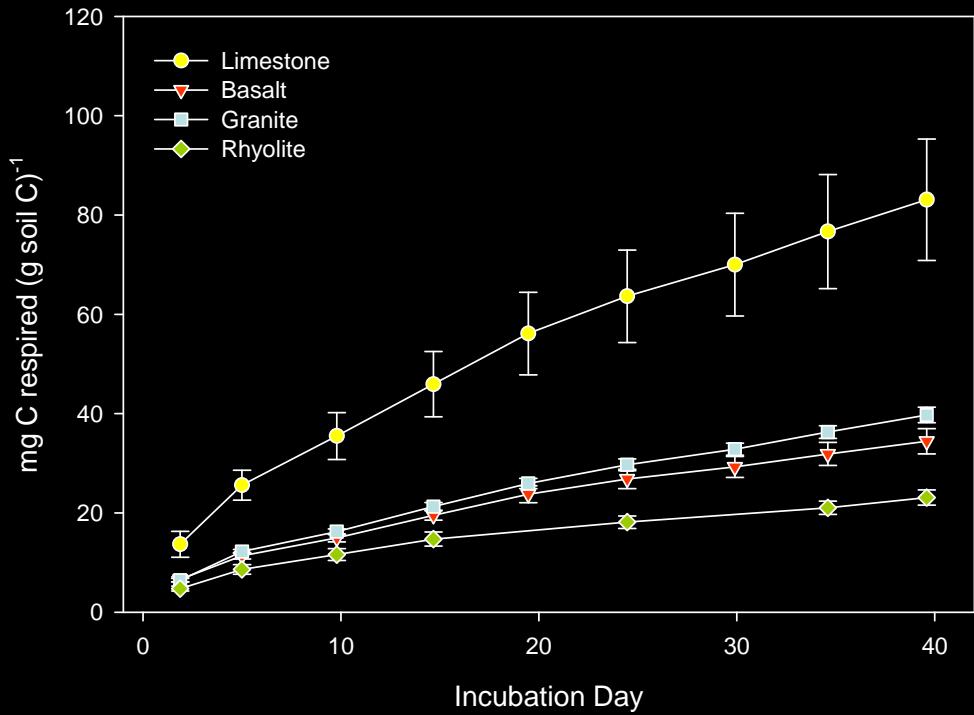
- Arizona Ponderosa Pine Forests
  - Al effects on microbial community structure and soil C sequestration
  - Lithosequence of four parent materials
    - pH gradient and variable soil mineral assemblage



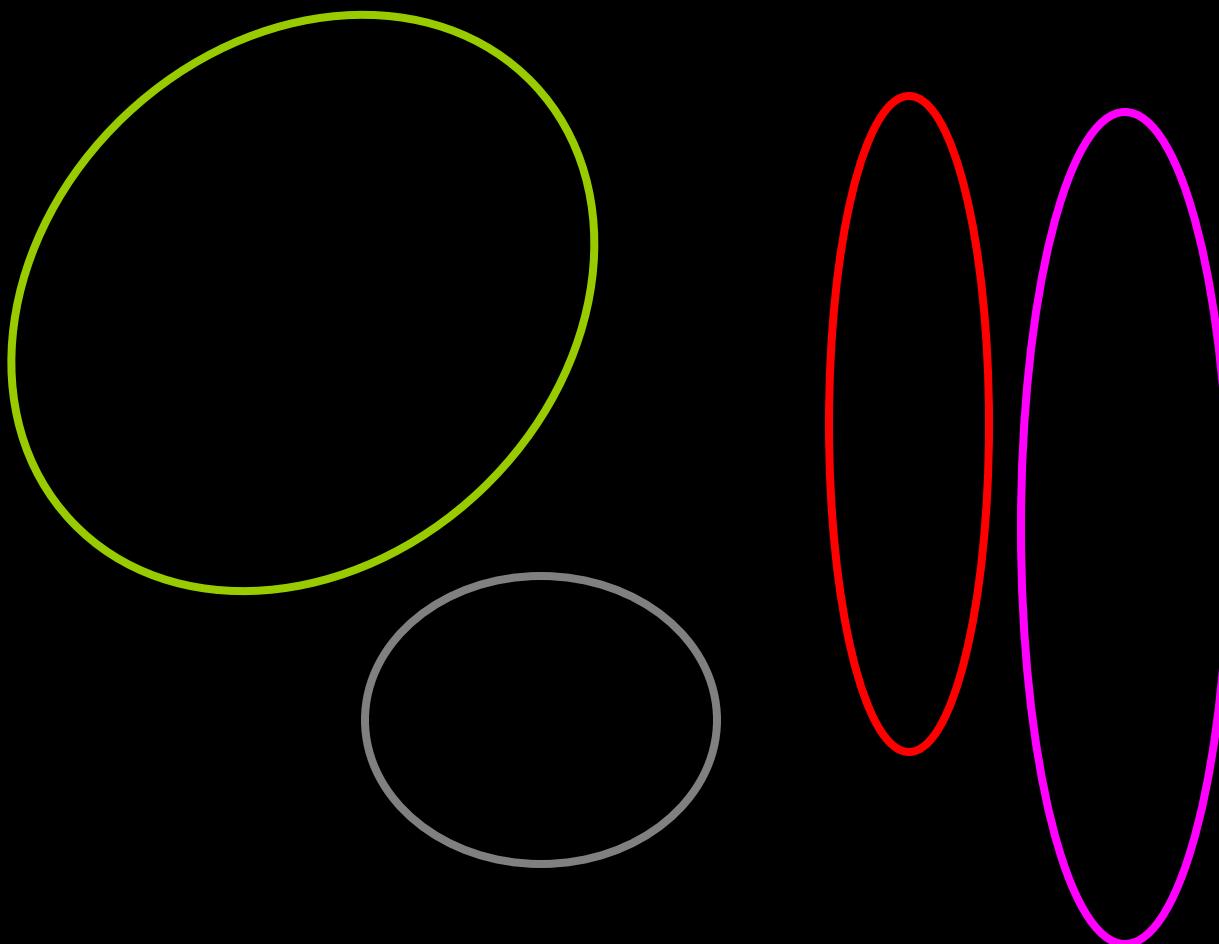


Significant correlation between soil C and metal-organic complexes

Significant variation in soil C mineralization by parent material



# Microbial Community Composition



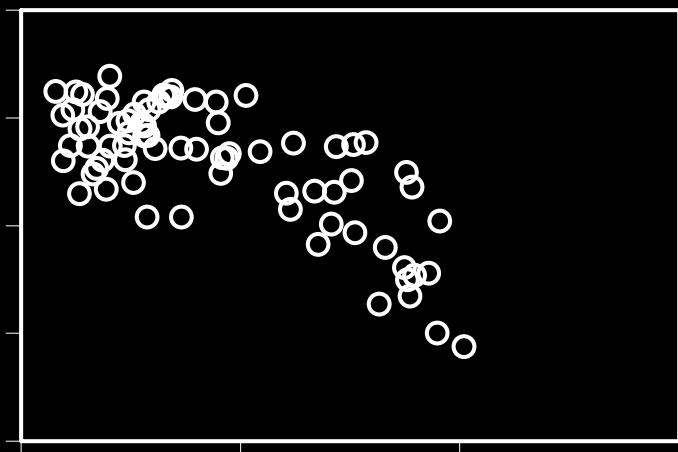
Significant variation  
by parent material

Correlated with:

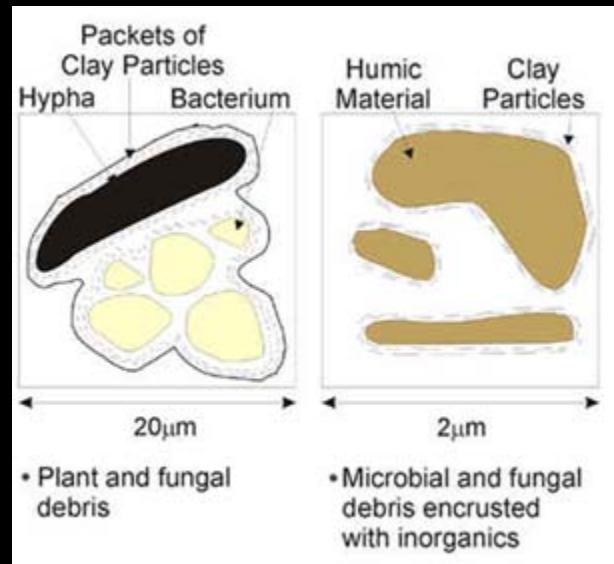
- pH
- exchangeable Al
- metal-organic complexes
- SRO Fe-oxides

# Microbial Community Composition

- Soil pH, diversity and Al-tolerant microbes



# Study 3: Physical Mechanisms

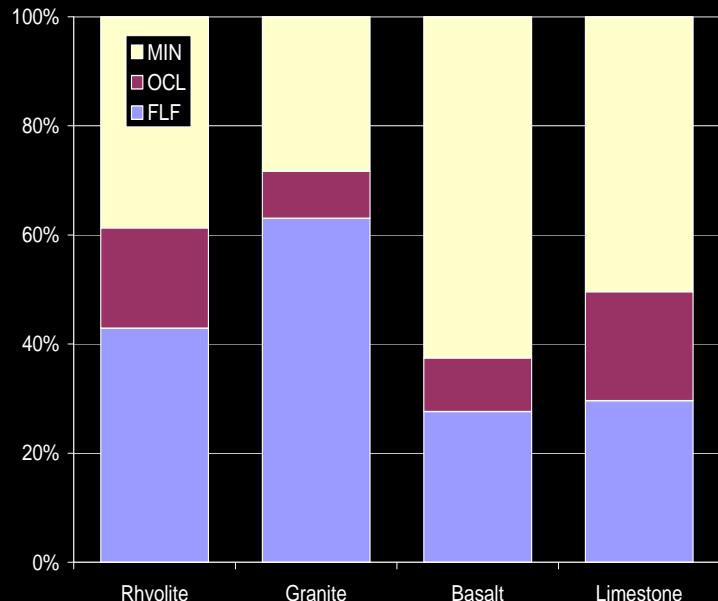


Free Light Fraction (FLF)

Occluded (OCC)

Mineral (MIN)

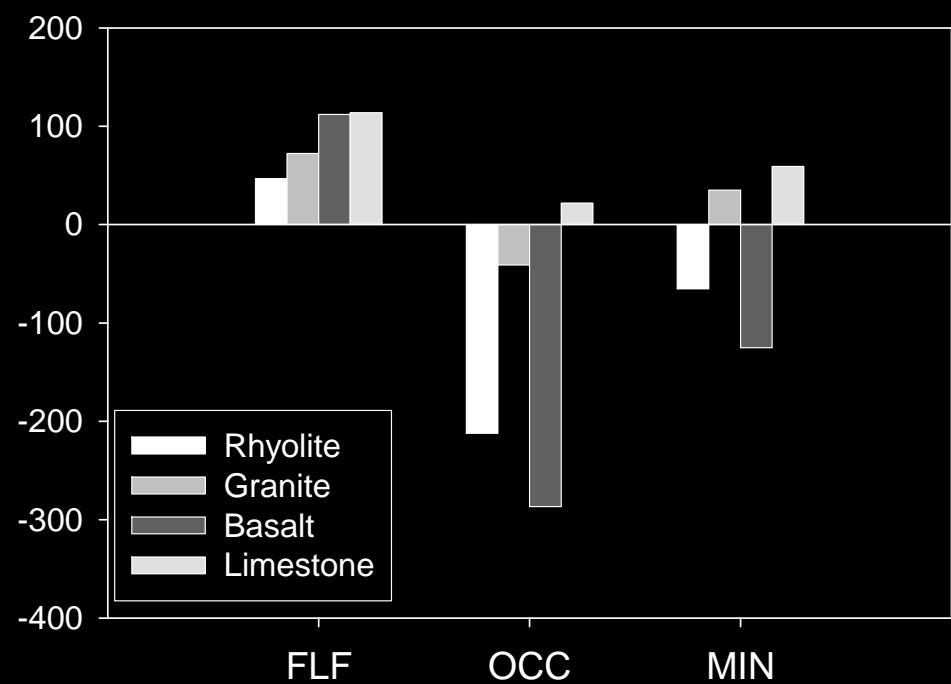
# Physical Mechanisms - Aggregation



"Young"

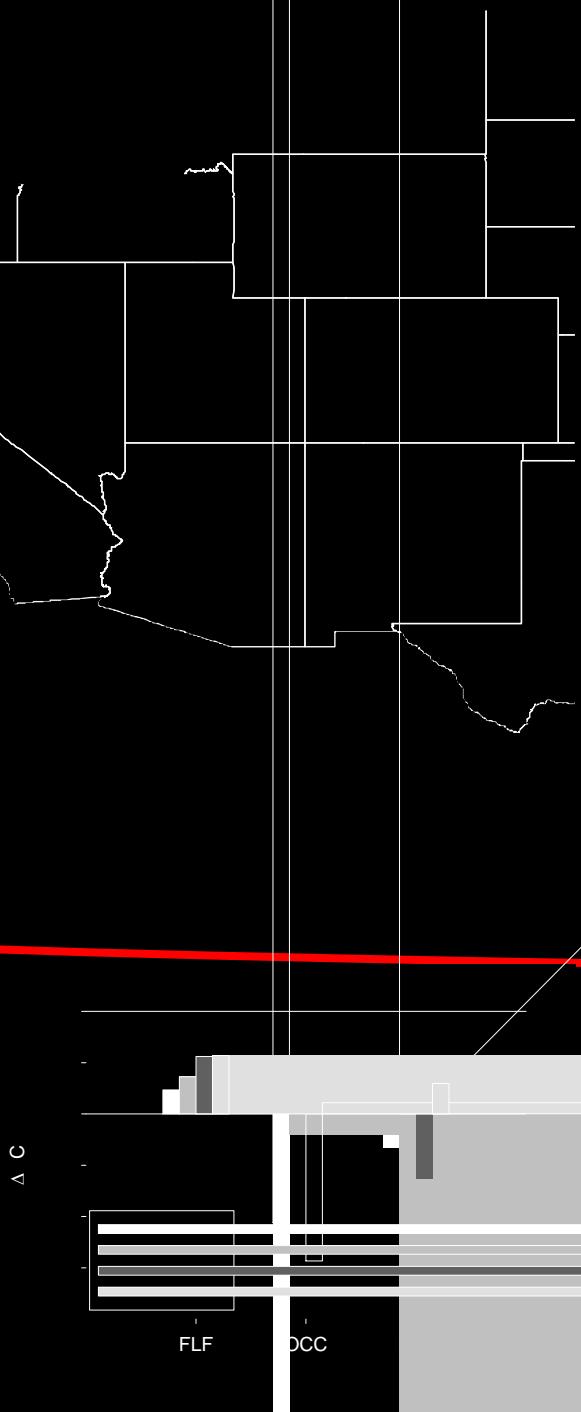
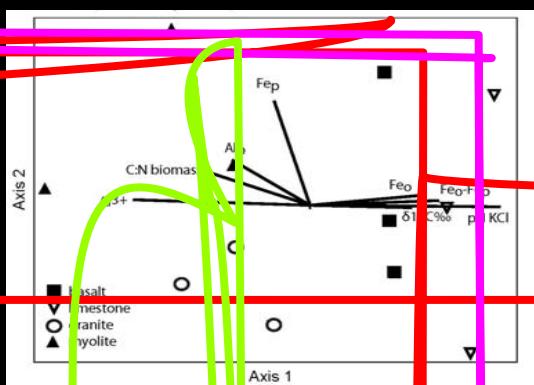
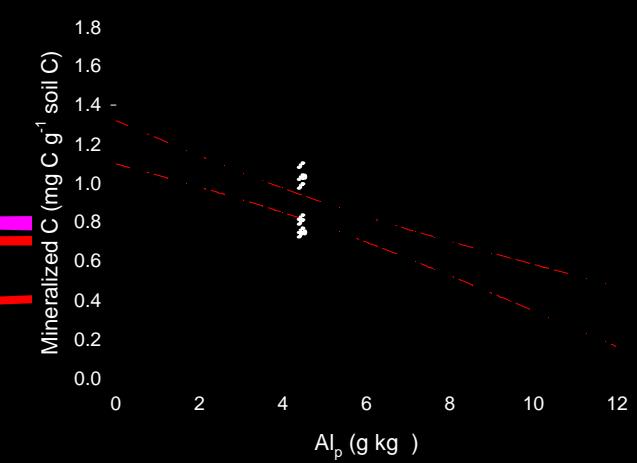
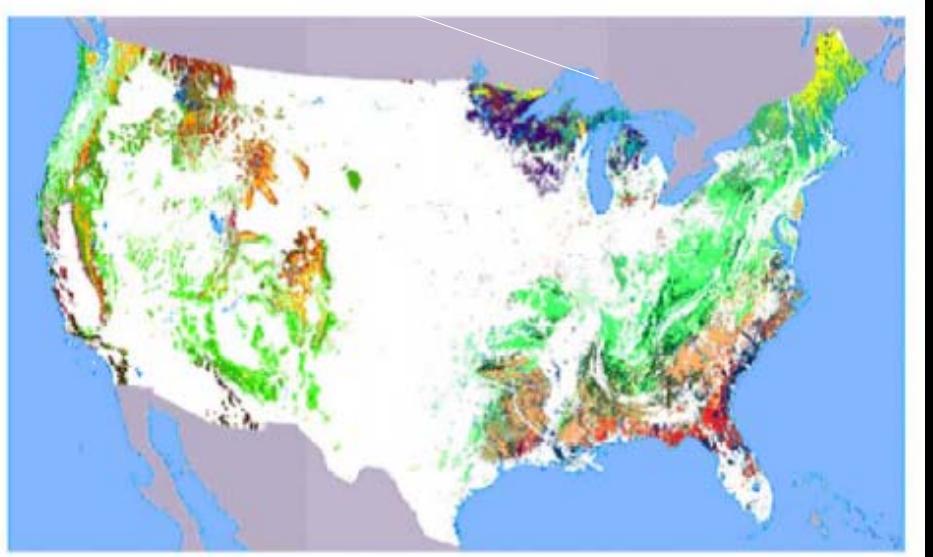
"Old"

$\Delta^{14}\text{C}$



# Overall Summary:

- Geology and soil mineralogy matter
  - Non-crystalline mineral species and metal-organic complexation
- Mineral control of soil C recalcitrance
  - Microbial community activity and composition
  - Chemical and physical protection mechanisms
- *Within a given ecosystem soil carbon sequestration varies predictably with geology*



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